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BALLISTIC MISSILE DEFENSES AND RUSSIAN RETALIATION ISSUES

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UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY

Preface

This report presents an examination of the degradation of a Russian retaliatory nuclear strike if the U.S. and Russia were to deploy theater or anti-ballistic missile defenses in their homelands. Also, consideration is given to efforts for restoring the effectiveness of a Russian retaliation, and the effects on first strike stability of deployments of theater missile defenses in one or both homelands.

This report should be of interest to personnel within the arms control and defense communities, as well as to others concerned with issues related to theater missile defense and anti-ballistic missile defense systems. The present effort is but one part of an overall project concerned with theater and ballistic missile defenses, their possible effectiveness, and related arms control issues. Previous related reports are concerned with the effect of deployment of theater missile defenses in the homeland of Russia and the degradation of a U.S. retaliation [1], and the exploration of concepts for boost phase intercept of ballistic missiles deployed by third world nations [2].

The author is indebted to Glenn Kent for suggesting the subject matter of this report. Thanks are extended to members of the U.S. Arms Control and Disarmament Agency for their encouragement, discussions, and comments concerning these analyses. This project was sponsored initially by Nyland Enterprises, a private organization concerned with issues related to arms control, defense, and public policy.

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RETALRUS.MSS

I - INTRODUCTION

The purpose of this report is to examine the effects of a United States deployment of a theater missile defense (TMD) or of a limited anti-ballistic missile (ABM) system in their homeland, and its relationship to a Russian retaliatory strike should the United States initiate nuclear conflict by striking first. The effects of such a deployment could degrade the Russian retaliation, thus raising Russian apprehensions about deterrent capabilities of their forces as they might exist under the START II Treaty.

In a previous report [1], the deployment of TMD in Russia to protect the homeland was considered. In that report, the effects of the U.S. retaliation, its potential degradation, and means to offset such degradations were considered. First strike stability was also considered, and it was shown that the deployment of ballistic missile defenses would degrade this particular stability measure unless certain countermeasures could be employed by the U.S. or Russia. In the present report, attention is directed to the implications for a Russian retaliation after a first strike by the U.S.

As a first order of analysis, we will describe a model for estimating the effectiveness of a ballistic missile defense. The model chosen for this analysis is that of a random subtractive defense against the re-entry vehicles of either side. Since neither side in the imaginary conflict has actually deployed any significant ballistic missile defenses, this model captures the essence of the factors involved. Chapter II will describe the assumptions that provide the foundation for this model, and allude to more complicated representations such as an adaptive preferential defense.

The threat is of great concern to both Russia and the United States. For this analysis, we have assumed that the force structures on each side comply with START II. Chapter III displays the assumptions that are used in this analysis, based on forces described in the open literature. The postures of the forces (their alert rates and at-sea rates) are based on assumptions made by the author. Rates of alert are varied in this analysis to show their effect.

Restoring the effectiveness of the Russian retaliation is considered in Chapter IV. This chapter is divided into three parts. The first part considers placing more weapons on alert to offset the effects of defenses. The second part includes the effect of specific countermeasures, i.e., the effect of perfect decoys accompanying the re-entry vehicles (RVs) to assist in countering the effects of a ballistic missile defense. A third part presents an analysis of discrimination between decoys and

RVs in the event that decoys are not perfect, i.e., the defender can determine to some extent which objects are decoys, and which objects are actually RVs. Under this condition, more decoys may be necessary to enforce damage levels desired by the retaliator.

First strike stability under a variety of conditions is examined in Chapter V. Variations include the amount of defense, the alert rate, and the use of decoys. In particular, one case where Russia deploys defenses but the U.S. does not will be considered. Under these conditions, first strike stability does not degrade if the U.S. deploys credible decoys as a countermeasure to the Russian ballistic missile defense.

Finally, observations and remarks about trends are presented in Chapter VI. References, denoted by numbers in brackets, will be found at the end of the report.

II - ASSUMPTIONS ABOUT BALLISTIC MISSILE DEFENSES

Since neither the Russians nor the United States have yet deployed theater missile defenses, their exact nature is not yet precisely defined. For this reason, we will consider a simple but representative model - a random subtractive defense. The model will include the effect of decoys.

When decoys are assumed to be perfect, then the random subtractive defense can be represented by

1) $P(\text{penetration}) = 1 - (1-L)\cdot DP/(RV+D)$

when the number of re-entering objects (RV+D) is greater than the defense potential (DP). The number of ballistic missile re-entry vehicles is denoted by RV, and the decoys by D. The leakage rate is L, and the defense potential is DP. The defense potential is defined as the maximum number of re-entering objects that the defense system can engage before depleting its supply of interceptors. If the number of re-entering objects exceeds the defense potential, then the objects in excess of the defense potential will penetrate without opposition. The probability that the defense can negate a re-entering object is simply (1-L). One unit of defense potential could be the committment of a single interceptor, or the committment of a salvo of interceptors. In this analysis, we assume a robust defense which is represented by a leakage rate of 0.1. If the reader doubts that a single interceptor can counter a re-entering object with a probability of 0.9, then one unit of defense potential could consist of two interceptors with a probability of countering a re-entering object of approximately 0.68. Another option would be to set one unit of defense potential equal to a salvo of three interceptors, each with a probability of countering a re-entering object of approximately 0.53.

When the defense potential is greater than the number of re-entering objects, then we assume that the units of defense potential are allocated uniformly against all objects. If the ratio of defense potential to re-entering object is integer, then

2) $P(\text{penetration}) = 1 - L^{[DP/(RV+D)]}$

If the ratio of defense potential is not integer, then the allocation directs that some re-entering objects will be countered by one more defense potential unit than committed to others.

3) $$P(\text{penetration}) = [1-FP[DP/(RV+D)]\cdot L^{INT[DP/(RV+D)]} + FP[DP/(RV+D)]\cdot L^{INT[DP/(RV+D)+1]}$$

where INT(x) represents the integer part of the quantity in

parentheses, and FP(x) represents the fractional part of the quantity in parentheses.

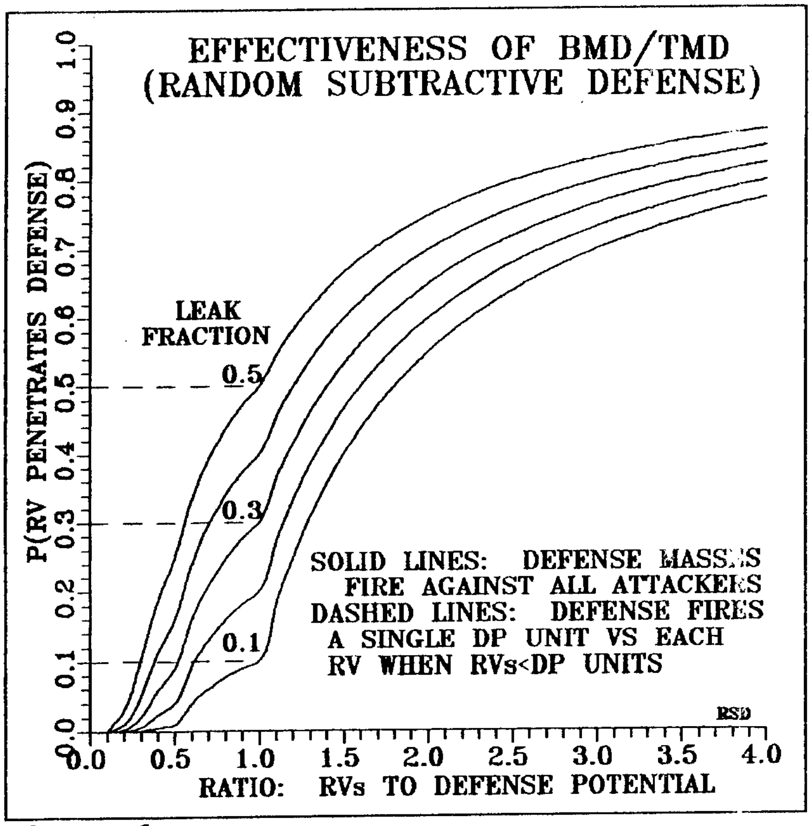

Figure 1

In the view of some analysts, a cautious defender would not commit all units of defense potential against small attacks, but might withhold some resources to counter additional waves of re-entry vehicles. Under these conditions, the probability of penetration would simply be L, the leakage rate when the defense potential is greater than the number of re-entering objects. In this analysis, we assume that the defense knows that all available re-entering objects have been launched, and that all available units of defense potential are committed to negating the attacking force. Under the conditions of this analysis, particularly when the defenses are large in number compared to the attack size, then the environment is defense dominant, i.e., the defense can stop nearly all incoming objects. Figure 1 indicates the probability of penetration as a function of the ratio of re-entering objects to units of defense potential. The dashed lines indicate the more cautious committment of defense resources when the units of defense potential are greater than the attacking objects. The solid lines indicate the effect of massing all defensive firepower when the defense potential is greater than the number of attack objects.

When decoys are not perfect, then the analysis becomes more complicated. In this report, we rely on a method developed by S. Layno [3] during the ABM debate of the late sixties. His method yields the same results as the above analysis when decoys are perfect, but allows the investigation of less than perfect decoys when the defender has some capability to discriminate between

decoys and re-entry vehicles. Under this method, the number of perceived RVs is given by

4) $PRV = (1-f) \cdot RV + g \cdot D$

and the number of perceived decoys is given by

5) $PDC = (1-g) \cdot D + f \cdot RV$

where f is the probability that an RV is perceived as a decoy (D) and g is the probability that a decoy is perceived as an RV. When the defense minimizes the probability of penetration of the re-entry vehicles, the number of units of defense potential committed against perceived RVs becomes

6) DP commited vs PRVs = $PP1 \cdot PP2$

where PP1 is a uniform allocation of units of defense potential

7) $PP1 = DP \cdot PRV/(PRV+PDC)$

and PP2 is unity plus a hedge factor based on misperceptions and defense effectiveness.

8) $PP2 = 1 + PDC/DP \cdot \log_e[PRV/PDC \cdot f/(1-f)]/\log_e(L)$

The decoys are assumed perfect when the probabilities of perceiving RVs as decoys and perceiving decoys as RVs are each set to a value of 0.5. Usually, the two probabilities are set equal to each other, and in this analysis this value is labeled as a "confusion factor."

Some analysts have suggested that an adaptive preferential defense would be more effective than a pure random subtractive defense model. These differences have been examined by Kent [4] and have been shown to be slight (about 5% or less). While the work that Kent presented was for a scaled down attack and scaled down defense scenario, the author has verified that the same results obtain for full scale attacks involving thousands of RVs and robust defenses. The results obtained by Kent do rely on a very specific allocation of decoys accompanying RVs. Those RVs aimed at high value targets would be accompanied by more decoys than those RVs aimed at lower value targets. The allocation is constructed so that the defense would save an equal amount of target value no matter which group of decoys and an RV were brought under defensive fire.

A defender employing an adaptive preferential defense doctrine would commit interceptors first against RVs unaccompanied by decoys, and then commit interceptors against RVs having fewer decoys. This technique assumes that the defender's

sensors detect the entire attack before any RVs arrive at their targets, so that the adaptive allocation can take place prior to impact of the first RVs. The advantage of Kent's approach is that such a complete knowledge of the attack is not needed, that is, the defender simply procedes to do the best that he can. The defender does not accomplish as much as one using preferential and adaptive techniques, but he comes close. If the attacker were to send a single decoy not accompanied by an RV against targets in excess of the RV inventory, then the adaptive preferential defense might not perform as well as indicated in this analysis. This option for the attacker has not been examined here.

The final assumption concerning the defense concerns the strategy of the defender. In this analysis it is assumed that the defense is deployed to protect so-called "value" targets. The defense is not used to protect strategic forces. The reason behind this assumption will be discussed further in the next chapter.

III - OFFENSIVE FORCES AND TARGET VALUES

This chapter presents assumptions concerning the offensive forces of the United States and Russia under the terms of the START II Treaty [5]. This treaty has been ratified by the U.S. Senate and the assumption is that the Russian Duma may follow the same course.

The force structures and postures assumed for purposes of this analysis are given in Table 1, below.

Table 1 - Strategic Force Structures and Postures Under the START II Treaty

Number of Vehicles	System Name	Warheads per Vehicle	Total Warheads	Alert Fraction
United States				
500	Minuteman ICBM	1	500	1.0
336	Trident SLBM (14 SSBNs)	4	1344	0.64
66	B-52 bombers	20	1320	0, 0.33
20	B-2 bombers	16	320	0, 0.33
Russia				
105	RS-18M (silo)	1	105	1.0
360	RS-12M (mobile)	1	360	0, 0.50
350	RS-12M (silo)	1	350	1.0
120	SLBM (6 Typhoon SSBN)	6	720	0.33
112	SLBM (7 Delfin SSBN)	4	448	0.29
176	SLBM (11 Kalmar SSBN)	3	528	0.27
50	TU-95MS bombers	12	600	0, 0.30
10	TU-160 bombers	12	120	0, 0,30

Total Warheads: Russian = 3231, U.S. = 3484

The data in this table for the U.S. is drawn from the Military Balance [6], and that for Russia is based on an article by Anton Surikov [7] of the USA and Canada Institute. The assumptions concerning alert rates are those of the author. The first fraction indicates what will be termed Posture A, and the second (where it appears) is termed Posture B. Posture A represents what is believed to be the current situation - no strategic bombers are on strip alert in either nation. Posture B indicates a possibility of higher alert rates for the bombers on both sides, and for the mobile ICBMs in Russia. For the submarines (SSBNs), the alert fraction is assumed equivalent to the at-sea rate.

In this report, we are concerned with a first strike by the U.S. and a subsequent retaliation by Russia. Table 2 indicates our assumptions concerning the surviving strategic forces in Russia after a first strike by the U.S.

Table 2 - Assumed Surviving Russian Warheads

System Name	Posture A	Posture B
RS-18M (silo)	17	17
RS-12M (mobile)	14	187
RS-12M (silo)	56	56
SLBM (Typhoon)	283	283
SLBM (Delfin)	157	157
SLBM (Kalmar)	179	179
TU-95MS	24	204
TU-160	5	41
Aggregated Surviving Russian Warheads		
ICBMs	87	260
SLBMs	619	619
Bombers	29	245
Totals	778	1167

U.S. Warheads sent vs strategic forces = 1062 (990 vs ICBMs)

Further assumptions concerning strategic forces include availability and reliability rates for ballistic missiles of 0.8, and bomber escape and penetration rates of 0.9 and 0.9. The assumed single shot destruction probabilities are as follows: for ICBM silos, 0.6; for submarines in port, 0.7; for mobile missiles in garrison, 0.8; and for non-alert bombers, 0.8. Deployed mobile missiles, alert bombers, and submarines at sea are assumed to survive any strike. These assumptions apply to both the U.S. and Russia.

In this analysis, strategic forces are used to nearly destroy the enemy's strategic capabilities, and any remaining warheads are then directed at what we designate as value targets. Value targets consist of other military targets, national and military leadership, and war supporting industrial facilities. In succinct terms, value targets taken as a whole make up a nation's force projection capabilities. We assume that these value targets are defended by some sort of ballistic missile defense, if it is present. We further assume that strategic forces on either side are not defended against ballistic missile attacks. The reason behind this latter assumption is that strategic force elements have their own forms of passive defenses - hard silos or mobility for ICBMs, deployment to sea for SLBMs, and strip alert for bombers. In many instances, passive defenses

are attractive because they seem to be less expensive than active defenses.

The number of value targets in Russia is assumed to be 2500. This number of targets is based on a study by Bennett [8]. The author assumes that the value of these targets is distributed according to an economic theory by Pareto. Under this assumption, the value at risk by an attack of n warheads is the square root of the quantity n/t, where t is the number of value targets. The number of value targets in the U.S. is assumed to be 1600, again following a Pareto distribution.

IV - EFFORTS TO RESTORE RUSSIAN RETALIATION EFFECTIVENESS

The purpose of this chapter is to examine a number of ways in which the Russian retaliatory strike might be improved in the presence of U.S. theater missile defenses or a limited ABM system. The discussion is divided into two parts: 1) increasing the on-line alert rate of Russian strategic weapon systems, and 2) the employment of countermeasures to improve the probability that re-entry vehicles will penetrate ballistic missile defenses. The base case assumption for both discussions is that Russian forces are in posture B (bombers on strip alert and mobile ICBMs deployed away from their garrisons). The results of the analyses will be presented in a graphical format where the y-axis is the number of weapons needed to achieve a desired damage level against value targets as a function of the number of units of defense potential (x-axis) deployed to counter a Russian retaliation. The parameter will be the fraction of damage against value targets.

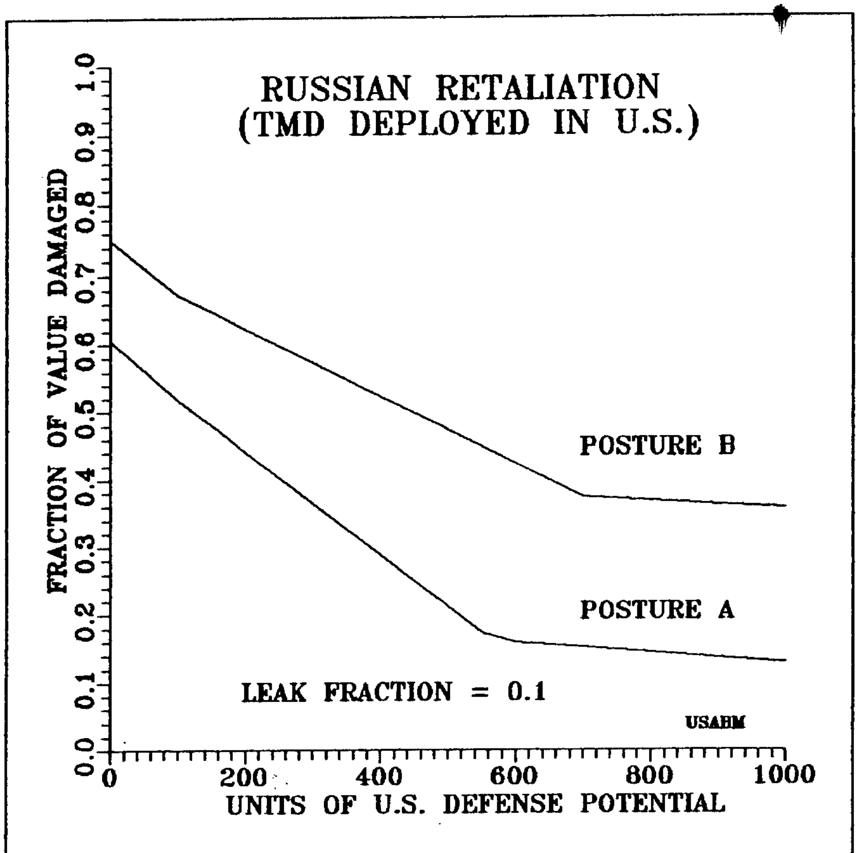

Figure 2

Before indicating efforts at restoration of the effectiveness of a Russian retaliation, the effect of the deployment of a U.S. ballistic missile defense is estimated. For the assumed Russian forces, and the assumed survivors of a first strike by the U.S., Figure 2 indicates the degradation of the Russian retaliation in terms of the fraction of damage inflicted on U.S. value targets as a function of the defense potential deployed by the U.S. The degradation in the effectiveness of the retaliation as a function of U.S. defense potential seriously degrades for either of the assumed force postures. Thus, Russian military leaders might be expected to

examine options for restoring effectiveness, even if only partially.

Restoring Retaliation Effectiveness with Increased Alert Rates

In this discussion, the number of Russian strategic weapons needed to enforce different levels of damage to U.S. value targets will be estimated. A basic assumption is that the Russian forces would be in Posture B when the U.S. strikes first with nuclear weapons. Under this assumption, and assuming that neither side has deployed a ballistic missile defense system, the Russian retaliatory strike will damage about 75% of the value targets in the U.S. The next step in the analysis will be to determine how many more ICBM, SLBM, and bomber warheads should be put on alert or put to sea to maintain this level. Failing to maintain a desired level of damage, some other lower level of damage to American value targets may have to be accepted.

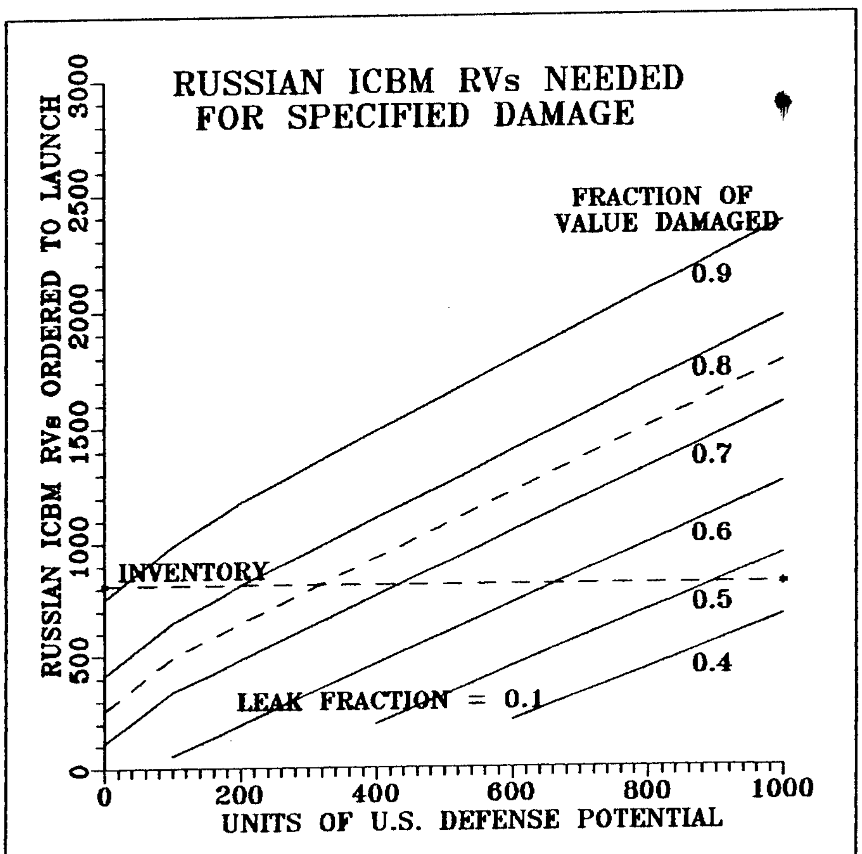

Figure 3

The Russians could deploy more mobile ICBMs away from their garrisons to counter the effects of a U.S. deployment of a ballistic missile defense. Figure 3 shows estimates of the number of ICBM warheads ordered launched to achieve several damage levels as a function of the number of units of defense potential the U.S. might deploy in the future. The unlabeled dashed line indicates that 75% damage would be inflicted against the U.S. value target system. If the U.S. were to deploy about 300 units of defense potential, the entire inventory of Russian ICBMs would be needed to restore retaliation effectivess. For larger deployments of ballistic missile defenses, the Russians would have to accept lower damage levels.

Would increased deployment of ballistic missile submarines offset U.S. ballistic missile defenses? Up to a point, according to the estimates provided in Figure 4. Under the assumptions provided earlier, about 619 SLBM warheads might normally be at sea, and thus invulnerable to a U.S. first strike. If the U.S. were to deploy about 400 units of defense potential, then the effectiveness of the Russian retaliation could be restored by doubling the at-sea rate of the submarines. If the U.S. were to deploy 700 units of defense potential, then all Russian submarines would need to be at sea to maintain the damage level inflicted when no defenses were deployed. If 619 SLBM warheads were the limit of Russian capability for at sea rate, then the damage level would fall off appreciably as the U.S. deployed more and more defenses.

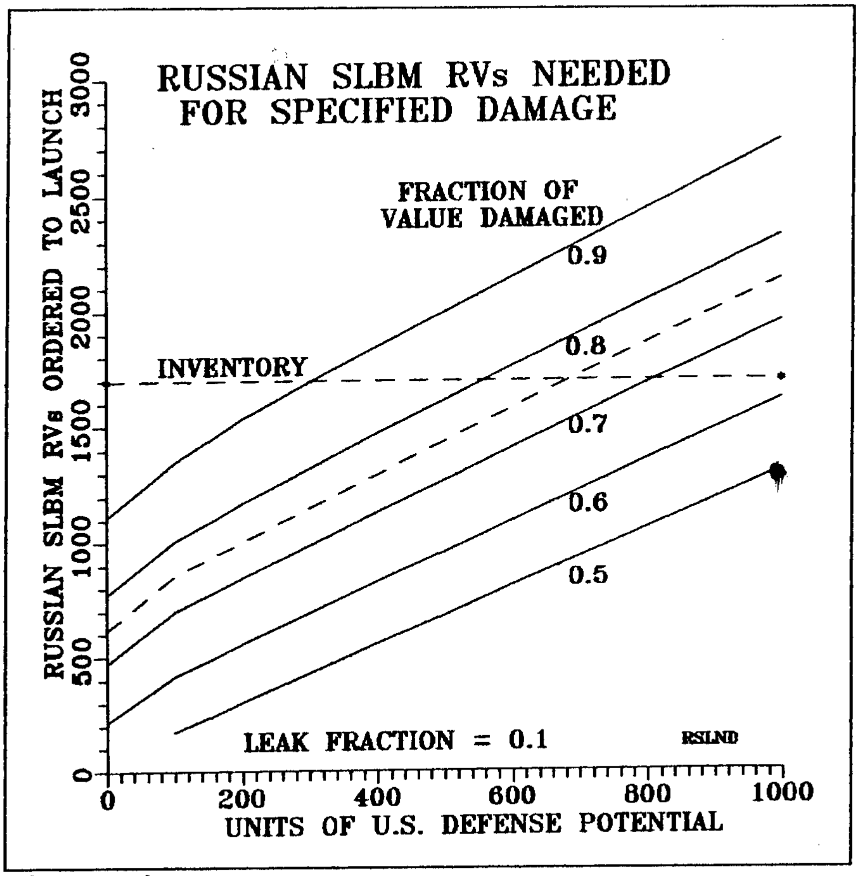

Figure 4

Russian bomber forces could be put on a higher rate of strip alert in an effort to offset the increased level of U.S. ballistic missile defenses. Bombers would not be affected by the deployment of ballistic missile defenses. Putting all of the Russian bombers on strip alert could offset about 300 units of U.S. defense potential as indicated in Figure 5. Further, if all bombers were on strip alert, about 60% of the U.S. value target system would be damaged for larger deployments of U.S. defense potential. The bending of the curves at about 700 units of U.S. defense potential indicates the point at which Russian RVs would come under attack by more than one unit of defense potential, thus limiting the effectiveness of the Russian retaliation.

From this discussion, we observe that increasing the alert rates of various elements of the Russian strategic nuclear forces could offset some levels of deployment of U.S. ballistic missile defenses, but in each case **the offsetting increase in alert rate would be limited even with heroic efforts on the part of the Russians to increase alert or at-sea rates.** The employment of countermeasures to the U.S. ballistic missile defenses might improve this situation.

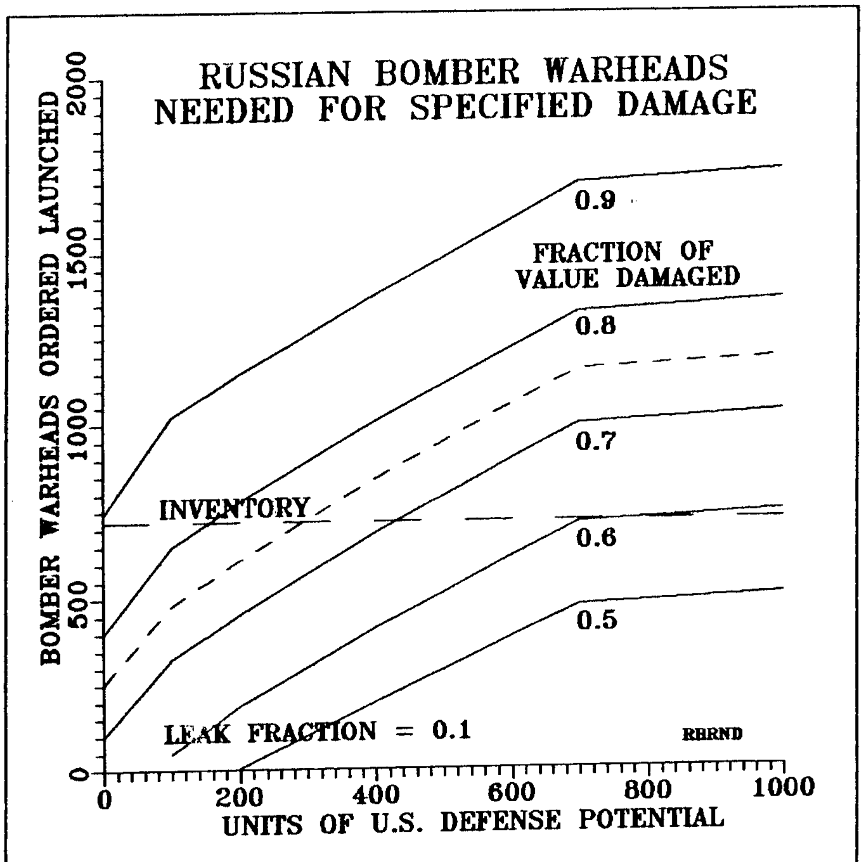

Figure 5

<u>Restoring Retaliation Effectiveness with Countermeasures</u>

In this discussion, alert rates and at-sea rates will be increased but with the additional strategy of employing decoys to accompany ballistic missile RVs. In what follows, the decoys are assumed to be perfect, and further, the number of decoys is assumed to be twice the number of RVs. Thus, the ballistic missile defense will be confronted by three times as many re-entering objects as was the case in the previous analyses.

Would payload constraints limit the number of decoys that the Russians could deploy on each of their ballistic missiles? Under the START II Treaty, the number of warheads on many of the Russian ballistic missiles has been reduced well beyond the limitations of their original design. In the case of the RS-12M, which was designed to carry but one warhead, the size of the warhead might have to be reduced to provide a capability to carry decoys as a penetration aid to U.S. ballistic missile defenses. As such, it is believed that such a warhead size reduction would not seriously affect the capabilities of this particular missile. All of the other Russian ballistic missiles originally carried

many more warheads than suggested in the assumed force structure used in this analysis. For these reasons, it seems reasonable to assume that Russian ballistic missiles could carry many decoys, perhaps more than assumed in this analysis.

The number of decoys accompanying each ballistic missile RV would be commensurate with the value of the target under attack by each RV. Although the number of decoys is considered to be twice as many as the RVs, an RV aimed at a high value target would have many more decoys accompanying it than would an RV aimed at a lower value target. In the extreme, very low valued targets might not be accompanied by any decoys. The number of decoys accompanying each RV would be determined so that the defense, no matter which target was being attacked, would perceive that the same amount of defensive firepower would be needed to save an equivalent amount of value.

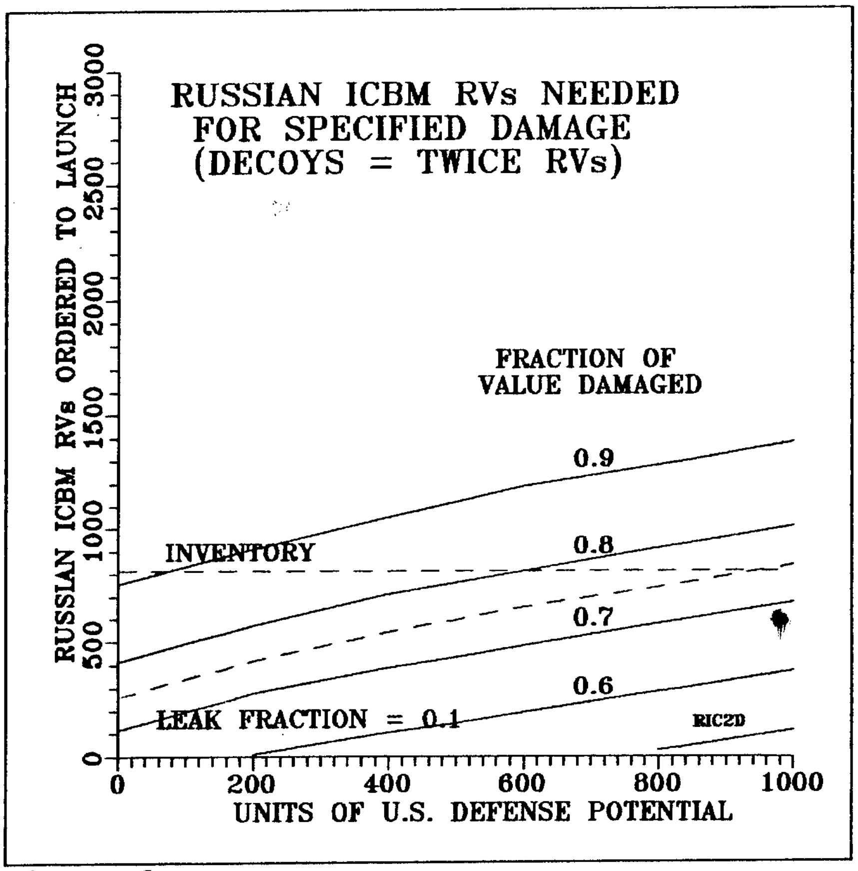

Figure 6

The needed increase in alert rate of Russian ICBMs combined with the use of decoys is indicated in Figure 6 to offset the increasing deployment of U.S. ballistic missile defenses. In contrast to previous analysis (see Figure 3), the slope of the lines indicating the fraction of damage to American value targets is much smaller. In the extreme, if all ballistic missiles in the Russian inventory of weapons could be put on alert or survive a first strike, then 75% of the American value target system would be put at risk even with a deployment of about 900 units of defense potential. Thus, considerable improvement would be realized through the use of credible decoys.

The same trends would be in effect for other elements of the Russian strategic forces if decoys could be employed. Figure 7 indicates a similar trend for SLBM warheads. Again, the slope of the curves is much less than in the previous case without decoys (see Figure 4). With twice as many decoys as RVs sent in the retaliation, a doubling of the submarines at sea would offset the deployment of about 1000 units of defense potential. Such an increase in the at-sea rate of Russian ballistic missile submarines, if all ballistic missile RVs were accompanied by twice as many decoys would have a beneficial effect, from the Russian point of view. Other benefits regarding first strike stability would also accrue, as will be discussed later.

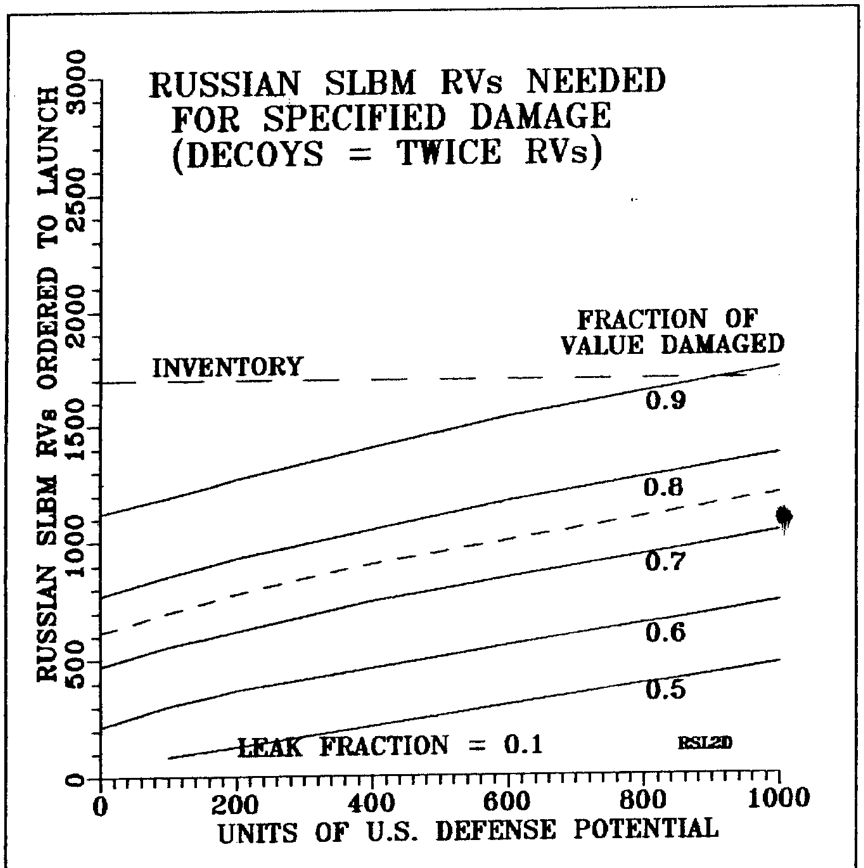

Figure 7

Increases in Russian bomber strip alert rates could also tend to offset some deployments of U.S. ballistic missile defenses. With no missle defenses deployed in the U.S., Russian forces would damage about 75% of the U.S. value target system. To maintain this level of damage at higher levels of missile defense, the bomber alert rate could be increased. Doubling the fraction of bombers on strip alert would offset about 350 units of U.S. defense potential. Figure 8 indicates this result. The rate of alert for bombers may be difficult to raise beyond the basic rate assumed here. Such increases in alert are much more expensive to maintain, or can be maintained only for short periods of time because of manpower and technical support limitations. To assure high probabilities of escape for the bombers when they are given warning, the aircraft would likely be dispersed away from their main operating bases, and such an action would tend to complicate maintenance and repairs to an even greater extent. Thus, while the analysis indicates that

increases in Russian bomber alert rates would be beneficial, there are probably some barriers to achieving such increases under actual operational conditions.

The use of decoys might alleviate Russian decision makers' apprehensions concerning the deployments of a theater missile defense or a limited ABM defense in the United States. The use of such countermeasures to the extent considered in this report would at least offset some levels of the deployment of ballistic missile defenses by the United States. Higher alert rates for Russian mobile ICBMs provides some relief, but the deployment of more ballistic missile submarines seems to offer the greatest potential for offsetting U.S. missile defenses, IF the Russians employ decoys to accompany all ballistic missile RVs. For example, doubling the at-sea rate of Russian ballistic missile submarines would offset the deployment of about 1000 units of U.S. defense potential. While the combination of increasing the alert rate of mobile ICBMs and the at-sea rate of SLBM warheads has not been considered here, the additional effect of the combination could be decisive in offsetting a large deployment of American ballistic missile defenses.

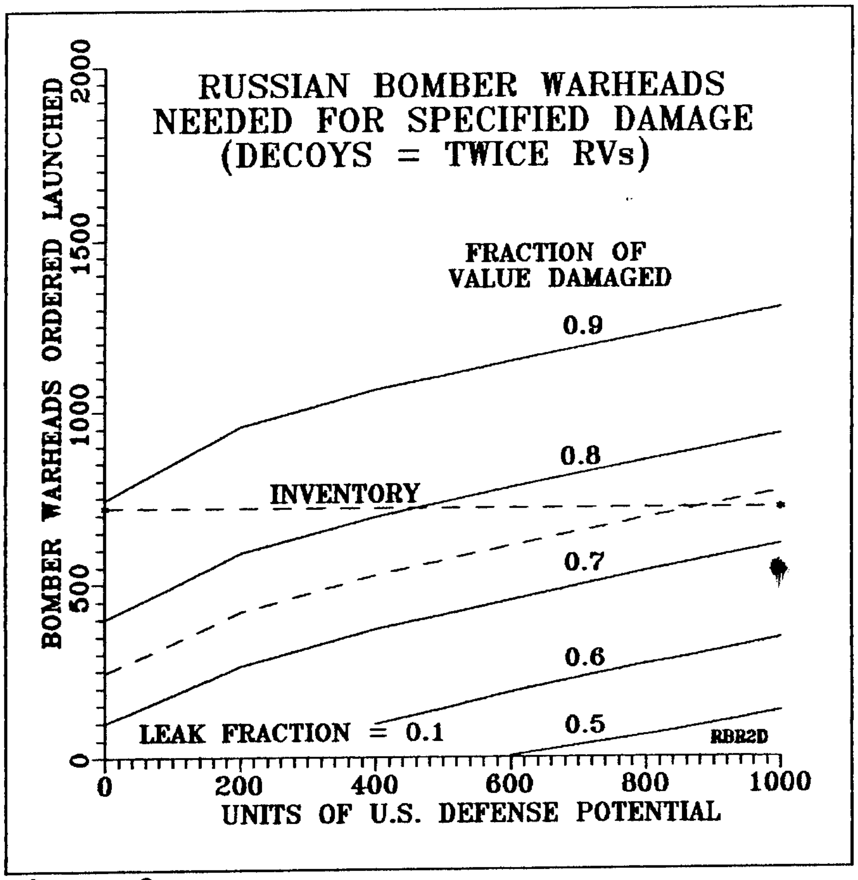

Figure 8

While the use of decoys might not completely restore the potential damage of a Russian retaliatory strike, the improvements possible under the assumptions concerning alert and at-sea rates would be a considerable improvement over no use of countermeasures to U.S. deployment of ballistic missile defenses. Figure 9 indicates the modest deterioration of Russian

retaliation effectiveness against the U.S. value target system with and without the use of decoys for two different postures of Russian strategic forces. The combination of Russian forces in posture B (bombers on alert) and the use of decoys to counter U.S. ballistic missile defenses would inflict heavy damage on the U.S. by a Russian retaliation. Even in posture A with decoys to accompany RVs, Russian forces could damage about half of the American value target system if 500 units of defense potential were deployed in the U.S.

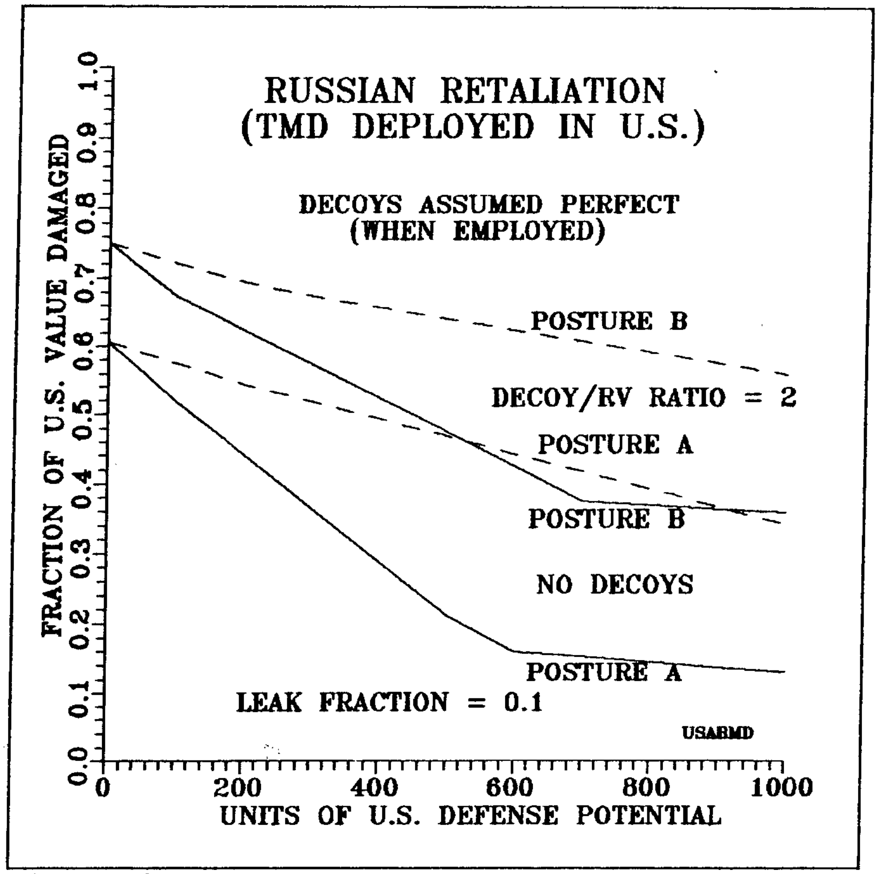

Figure 9

The Russians could decide to place more of their strategic forces on alert than was previously assumed (see Table 1). Up to this point, each element of Russian strategic forces has been varied to understand how many more warheads would be needed to offset the effectiveness of a U.S. ballistic missile defense. As one example, it is suggested that the alert rate represented by posture B be increased so that more warheads would survive a first strike and be available for a larger retaliation. The suggested increases in alert rate are: 1) 75% of the mobile RS-12M missiles would be dispersed away from their garrisons, 2) 50% of the SLBMs would be place at sea, and 3) 40% of the bombers would be placed on strip alert to escape a U.S. first strike (in posture B 50% of the RS-12M missiles were assumed dispersed, about 30% of the SLBMs were at sea, and about 30% of the bombers were assumed on strip alert). Figure 10 indicates the results of the assumed increases in dispersal, at-sea, and strip alert rates. One result is that the Russian retaliation would inflict more damage on the U.S. value target system. For example, without any ballistic missile defenses, the fraction of U.S. value damaged would rise from 0.75 to about 0.89. If the U.S.

were to deploy defenses, then the employment of perfect decoys would provide a significantly higher fraction of damage at higher levels of U.S. ballistic missile defenses. The ratio of decoys to RVs in this example is two. Without decoys, and assuming that the damage level desired by the Russians is about 0.75, the damage would fall below this value when the U.S. deploys 250 units of defense potential. In contrast, damage to the U.S. would be greater than 0.75 if the U.S. were to deploy 750 or fewer units of defense potential. As noted in previous discussions, using decoys to accompany RVs will tend to offset the effect of defenses. **Thus, the inclusion of perfect decoys on Russian ballistic missiles would provide a considerable leverage in maintaining the effectiveness of a Russian response to a U.S. first strike.**

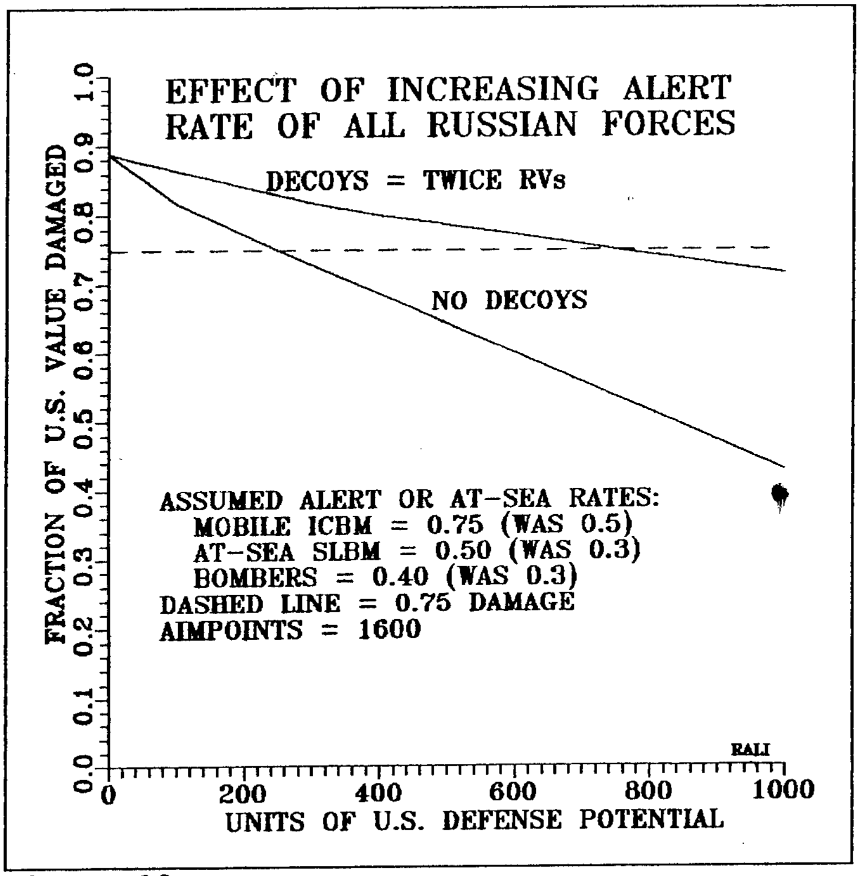

Figure 10

<u>Imperfect Decoys and Discrimination Issues</u>

In this part of the discussion concerning decoys, the assumption that decoys are perfect is varied. The battle outcomes between a defender trying to counter ballistic missile reentry vehicles (RVs) and an attacker employing decoys can vary over a wide range, depending on the credibility of the decoys. The discrimination capabilities of the defender count heavily when issues of discrimination arise. In this analysis, the major measure of credibility is called the "confusion factor." In an earlier chapter, a method of analyzing the effectiveness of defense against an attacker sending RVs and decoys was presented. The confusion factor is a measure which assumes that the probability of the defender perceiving a decoy as an RV and the probability of perceiving an RV as a decoy are set equal. When

decoys are perfect, the confusion factor is large, 0.5 or greater. When the decoys are completely ineffective, e.g. perfect discrimination on the part of the defender, then the confusion factor is lowest, zero. When the defender can discriminate partially between the two types of objects, then the cofusion factor lies between the limits of 0 and 0.5.

When it is assumed that decoys are perfect, then a substantially larger fraction of value targets can be destroyed, even in the face of a robust ballistic missile defense system. As confusion decreases, a smaller fraction of the value targets or aimpoints can be defended successfully. Figure 11 illustrates the degradation of the defense where the U.S. confusion factor decreases against a retaliation by Russia. In this figure, it is assumed that the Russian strategic forces are in posture B, i.e., about 30% of the bombers are on strip alert, about 50% of the mobile ICBMs are deployed away from their garrison compounds, and about 30% of the sea launched missiles are at sea. It is also assumed that the ratio of decoys to RVs is 2. Under these conditions, when the confusion factor decreases from 0.5 to 0.4, there is not much degradation in the value destroyed no matter how much ballistic missile defense is deployed. At lower values of confusion, then the fraction of value damaged is lower, as indicated in Figure 11. Thus, the issue turns to how many more decoys must be sent to maintain the same high level of damage if decoys are not completely credible.

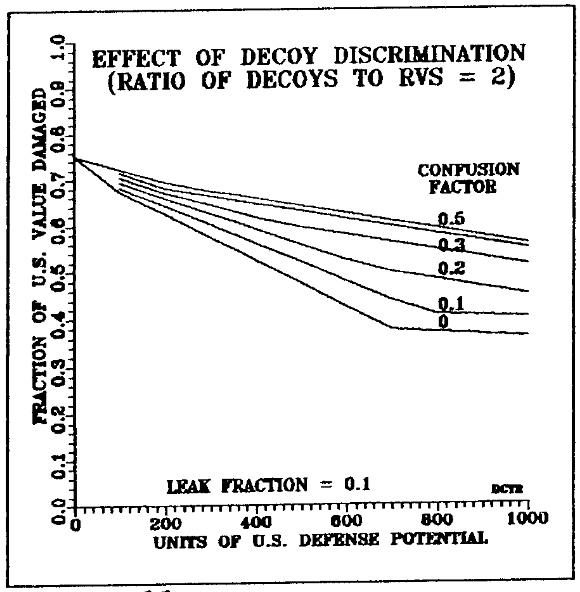

Figure 11

How many more partially credible decoys must be sent to maintain some expected damage to value targets? To answer this question, we will examine the effects of increasing the ratio of decoys to RVs from 2 to 4 and to 8. Figures 12 and 13 indicate the levels of damage to value targets at these increased ratios of decoys to RVs. In these figures, curves for confusion factors of zero are not shown because they are the same as that shown in Figure 11, i.e., the decoys are totally ineffective. Also, the curves showing the effect of a confusion factor of 0.4 are not shown because the differences from the curves for a confusion factor of 0.5 are slight. Decoys that cause a confusion of about 0.4 are almost as effective against ballistic missile defenses as completely credible decoys (confusion factor = 0.5). In both figures, there is a bend in some of the curves when the defenses

increase upwards, between zero and 200 units of defense potential. These changes in slope are a result of the assumption that bombers are assigned to higher value targets when their probablity of defense penetration is higher than that of RVs launched by ICBMs or SLBMs.

When the ratio of decoys to RVs is increased to 4, then the overall damage level would increase if the decoys are perfect. Figure 12 indicates this result. If the decoys are not perfect, but cause the defense confusion factor to be 0.3, then the same damage to U.S. value targets is maintained when the ratio of perfect decoys to RVs is 2. Thus, when decoys cause a confusion factor of about 0.3, then the attacker should send about four times as many decoys as RVs to maintain the same damage level as was achieved assuming perfect decoys.

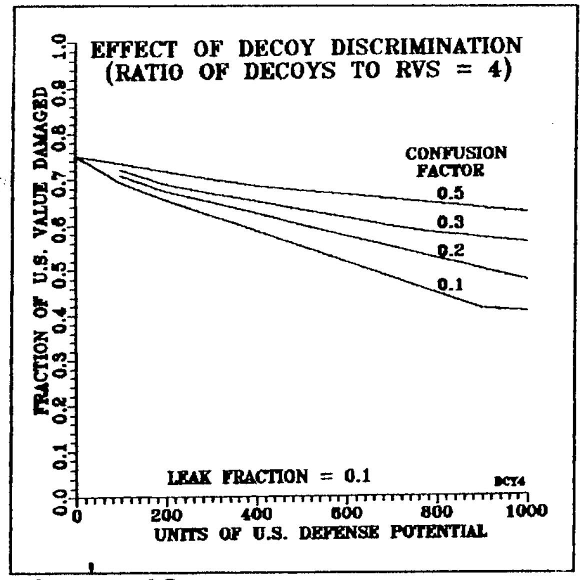

Figure 12

If the decoys were even more ineffective, but not totally useless, further increases in their use would be needed to maintain the same damage level achieved when decoys are assumed to be perfect. Another example, Figure 13, illustrates this effect. If the decoys are expected to cause the confusion factor to be 0.2, then the ratio of decoys to RVs must be raised to 8 to have the same resulting damage levels to U.S. value targets as would be the case when decoys are assumed to be perfect. If the decoy design turned out to better than expected, almost perfect, then a very high level of damage to U.S. value targets could be maintained across the entire range of ballistic missile defenses assumed here.

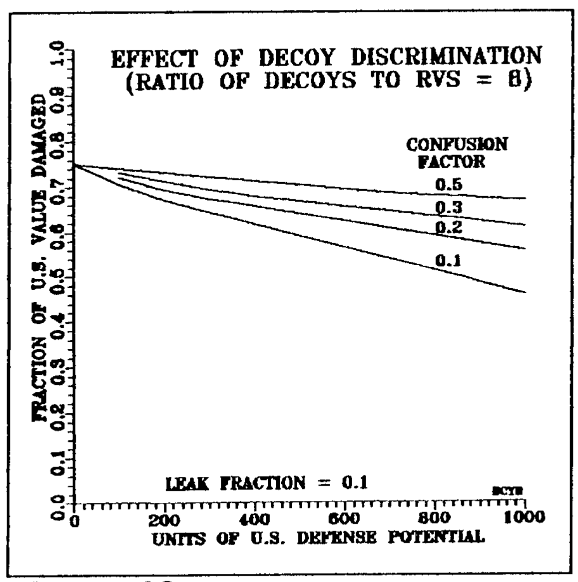

Figure 13

From this discussion, we observe that decreases in credibility (or increases in defense discrimination) can be offset by the attacker employing larger numbers of decoys to accompany the attacking RVs. If the confusion factor falls to 0.2, then the decoys must be about eight times as numerous as reentry vehicles to maintain the same levels of damage as when the ratio of perfect decoys to RVs is two. Further analysis has shown that if the confusion factor falls as low as 0.1, then the ratio of decoys to RVs must be 18 to maintain as much damage as when the ratio of perfect decoys to RVs is two. Whether or not such high ratios could be achieved on Russian ICBMs carrying a single warhead, such as the RS-12M, may be uncertain. Missiles designed to carry large numbers of RVs which have been off-loaded to comply with START II limits may be able to carry large numbers of decoys and still achieve their design ranges. Even though decoys may not be perfectly credible, their use would still provide a considerable advantage if used in a Russian retaliation to a U.S. first strike if the U.S. were to deploy up to 1000 units of robust defense potential.

V - FIRST STRIKE STABILITY

This discussion is focussed on first strike stability and how it is influenced by the deployment of ballistic missile defenses. The major parameters of concern include the posture of the forces on both sides, the extent of ballistic missile defenses, and the potential use of decoys by either or both antagonists. First, the method of estimating first strike stability will be outlined, and then the method will be applied to examples of interest.

First Strike Stability Methodology

The method of estimating first strike stability was developed by Kent and Thaler [9,10]. The basis for determining the index of first strike stability is the product of two ratios in a two sided confrontation. If the stability index approaches unity, then a stable condition exists. If the stability index is low, near zero, then the condition is unstable, i.e., one or the other side (or both) may be tempted to strike first. First strike stability is a quantifiable aspect of crisis stability.

First strike stability is the product of two ratios. Each ratio consists of the cost of going first compared to the cost of waiting and going second in a strategic exchange.

$$9)\quad FSS = [CUS1/CUS2]\cdot[CR1/CR2]$$

where CUS1 is the cost of the U.S. striking first, and CUS2 is the cost of the U.S. waiting and striking second. Similarly, CR1 is the cost of Russia striking first, and CR2 is the cost of Russia waiting and retaliating.

The so-called cost is related to the damage suffered plus a factor that is a measure of the damage not done to the opponent.

$$10)\quad C(US) = [(DUS)^{0.75}] + 0.3\cdot[1 - (DRUS)^{0.75}]$$

$$11)\quad C(RUS) = [(DRUS)^{0.75}] + 0.3\cdot[1 - (DUS)^{0.75}]$$

where C(US) is the cost to the U.S. and C(RUS) is the cost to Russia when either side attacks or waits. The damage suffered by the U.S. is DUS, and the damage suffered by Russia is DRUS. The attacker always tries to minimize the cost of going first.

The damage suffered by either side is the fraction of the value targets damaged. In this analysis, we make use of the Pareto distribution amongst value targets.

$$12)\quad DUS = (n/1600)^{0.5}$$

$$13)\quad DRUS = (n/2500)^{0.5}$$

where n is the number of warheads aimed at value targets. In particular, the Russians are assumed to have 2500 value targets, and the U.S. is assumed to have 1600 value targets. The exponent of the Pareto distribution corresponds to a square root function, but could take on other values based on specific target analyses.

The determination of damage levels and costs is determined by employing a model to analyze possible allocations of first strike weapons against the mixed force of the defender. Two runs are needed to find the cost for each side that is assumed to strike first. In the author's model, the number of warheads sent by a first striker is varied over considerable bounds to find the minimum cost to the attacker and the resulting cost to the defender. Similarly, a second run is made to determine costs when the attack and defense roles are reversed. Since the model also includes the effect of defenses (random subtractive), two runs are made for each level of defense considered. The results of these computations yield an index of first strike stability for each level of defensive firepower, measured in units of defense potential as indicated earlier.

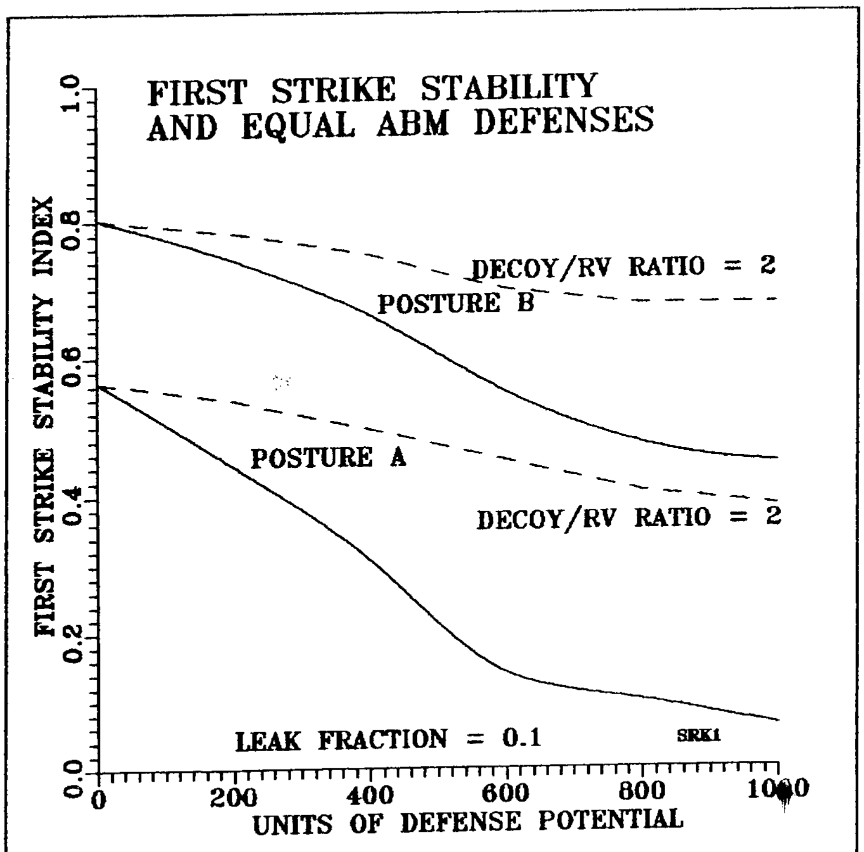

Figure 14

First Strike Stability Examples

The first example of first strike stability between Russia and the U.S. is based on the assumption that both sides deploy equal amounts of defense, and that both sides' forces are in postures A or B. The data underlying this analysis was outlined in Chapter III. Figure 14 shows the results in terms of the index of first strike stability as a function of the defense potential deployed by each side (assumed equal). Without the use of decoys by both sides, the index of first strike stability

degrades rapidly with the deployment of ballistic missile defenses. The alert postures of the forces do improve the first strike stability index. In general, the higher the alert rates, the higher the index of first strike stability. When decoys are used, the effect is to spoil the effectiveness of the ballistic missile defenses, thus increasing the index of first strike stability. When decoys accompany the RVs, the degradation of first strike stability is much less than when decoys are not employed by both sides. When alert rates are higher, and decoys do accompany RVs then first strike stability is not so sensitive to the level of defenses deployed by both sides.

The second example considered here is based on the assumption that the Russians have deployed various amounts of defense potential, but that the U.S. decides not to deploy any ballistic missile defenses, Figure 15 shows the results under these assumptions. Without the use of decoys to accompany RVs by the U.S., first strike stability degrades as Russia deploys defenses, but not as much as when both sides have ballistic missile defenses. When both sides are in posture A, the amount of degradation is worrisome when Russia deploys 1000 units of defense potential. If the U.S. employs decoys, the degradation seems modest as a function of the defenses deployed by Russia. In all circumstances, the posture of U.S. and Russian strategic forces makes a difference in first strike stability. From this example, we conclude that even though the Russians do deploy ballistic missile defenses, the first strike stability between the two adversaries would degrade gracefully if the U.S. can employ decoys to accompany their RVs, whether they strike first

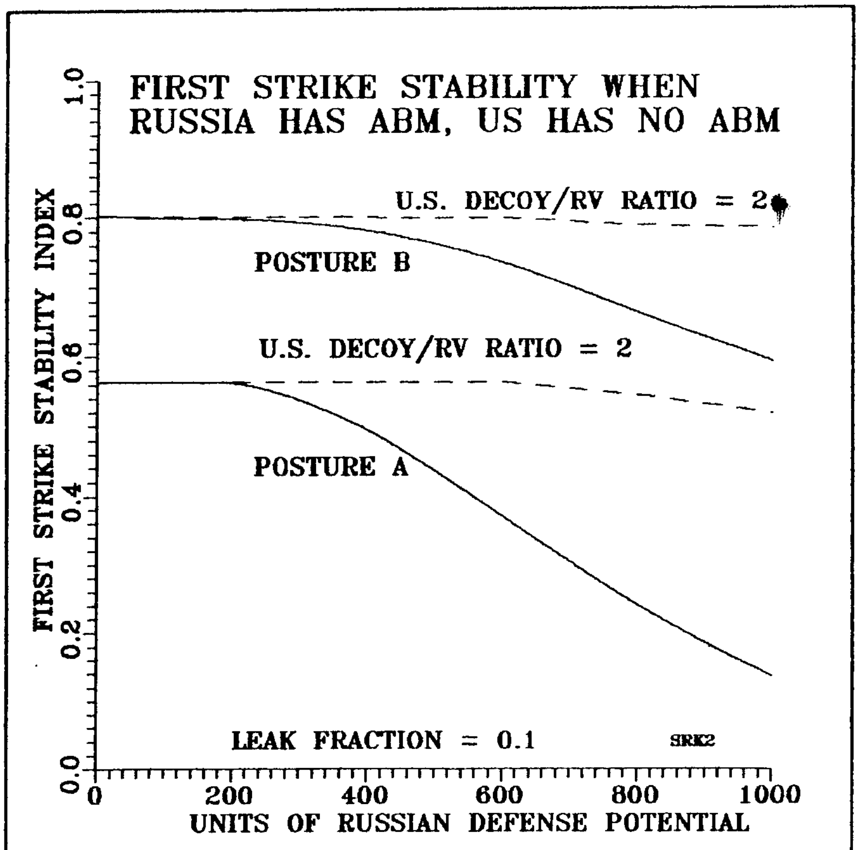

Figure 15

or second. The crux of the situation lies in the credibility of the decoys. In this example, the decoys were assumed to be perfect.

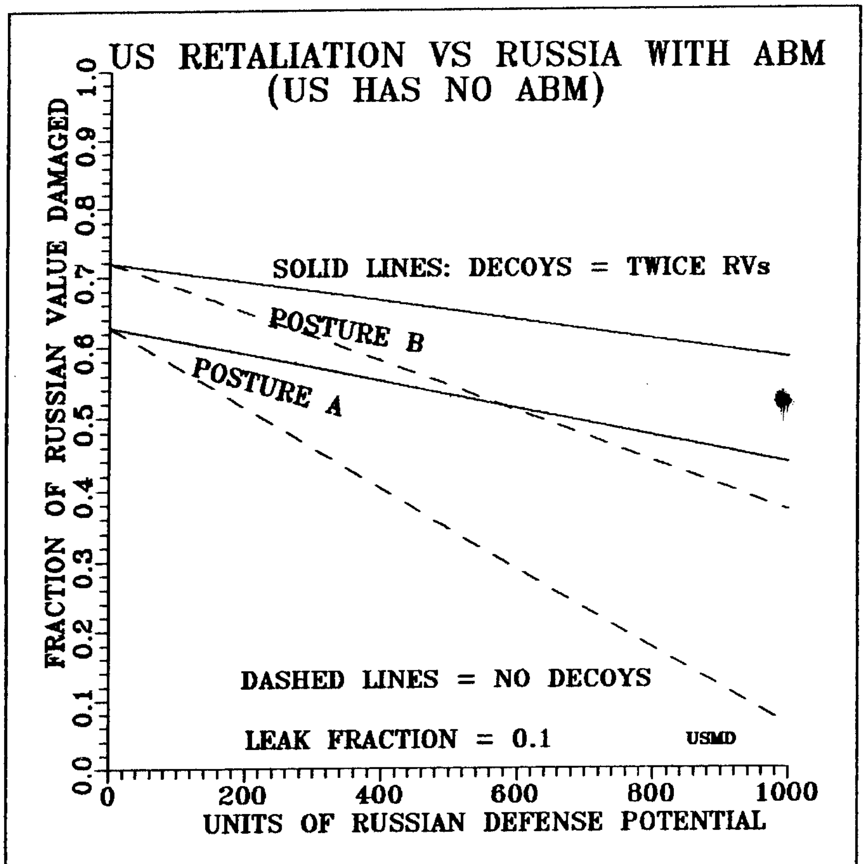

Figure 16

When the U.S. does not deploy ballistic missile defense, but the Russians do, what would be the effect on the effectiveness of a U.S. first strike? With the U.S. not deploying decoys, the effectiveness of a U.S. first strike degrades dramatically as a function of Russian defense potential, particularly for both forces in posture A. Even with higher alert rates, the degradation of the U.S. first strike is large although higher damage levels could be achieved. If the U.S. does employ decoys to accompany their RVs, then the degradation of effectiveness of the U.S. first strike is not so severe. These results are illustrated in Figure 16. Under the terms of this analysis, one option for the U.S. would be to deploy decoys on their ballistic missiles in response to a Russian deployment of theater or ballistic missile defense. From the results of this analysis, the U.S. would not need to respond to a Russian deployment of ballistic missile defenses by deploying its own ballistic missile defense. Under such a policy, first strike stability would not degrade significantly, and the cost of building a ballistic missile defense system could be avoided.

VI - SUMMARY AND OBSERVATIONS

This report has presented discussions concerning the possibility that both Russia and the U.S. might deploy theater missile defenses (TMD) or limited anti-ballistic missile defenses (ABM) in their homelands. The focus has been to examine the impact of such deployments on the potential degradation of the Russian retaliation to a U.S. nuclear first strike. In addressing this problem, we have presented models describing the effectiveness of random subtractive defenses and of first strike stability. The analysis dwelt on various means that Russia might employ to offset the effect of a U.S. ballistic missile defense and included placing more weapons on alert, and the use of decoys to degrade defense effectiveness. The effects of ballistic missile defense were examined with an eye toward first strike stability. The observations conclude this report with a discussion of each major issue. Assumptions about each issue are reviewed to provide the basis for the observations.

Force structures were chosen to comply with the START II Treaty signed by both heads of state. The U.S. strategic force structure was drawn from the Military Balance and modified by decreasing the number of warheads carried by each Trident missile (4 RVs per missile). The Russian strategic force structure was based on information available from a Russian analyst. Although both of these force structures comply with START II, there is no guarantee that they will be exactly correct. The force structures assumed here provide a basis for the analysis of future conditions which may change with time. The numbers of warheads were chosen to be but one representative case for purposes of analysis.

The postures of each force were selected by the author. Two major postures were assumed. In posture A, no bombers were assumed to be on alert. In addition, all mobile Russian ICBMs were assumed to be located in garrisons with well known locations. In posture B, some bombers (about 30%) on both sides were assumed to be on strip alert so that they could be launched on warning and survive a first strike. In addition, some Russian mobile ICBMs (about 50%) were assumed to be deployed away from their garrisons and would, presumably, survive a first strike. It was assumed that silo based ICBMs on either side would not be launched on warning of attack, and would suffer attrition. In both postures, some Russian SLBM submarines (about 30%) and some U.S. SLBM submarines (about 64%) would be at sea. The warheads carried by these submarines were considered invulnerable in a first strike. In one special case, it was assumed that the Russian strategic forces were placed on a somewhat higher alert rate to examine the damage to the U.S. as a function of U.S. defensive levels, with and without decoys.

Ballistic missile defenses for both sides were varied. In many cases in this analysis, the levels of defense exceeded the terms of the ABM Treaty (100 interceptors). The model used to describe the defense effectiveness is termed a random subtractive defense. The two parameters which describe this defense are the number of units of defense potential and the leak fraction. The number of units of defense potential is defined as the maximum number of re-entry objects (RVs and decoys) that can be engaged. The leak fraction is defined as the fraction of re-entry objects that penetrate the defenses even though they have been engaged. The defense potential was varied between 0 and 1000 units. The leak fraction was set at 0.1 to represent a robust defense, potentially a worst case. The strategy of the attacker, the U.S. in most of these analyses, was assumed to be to attack the Russian strategic forces first, and then turn to destroying "value" targets. The defense on either side was assumed to protect "value" targets, and not the strategic forces. The strategic forces on both sides have passive defense measures. In addition, it was assumed that the defense of either side would commit all of its potential when the number of re-entering objects was less than its defense potential.

As the level of U.S. ballistic missile defenses were increased, the effectiveness of Russian retaliation was substantially degraded. The measure of this degradation was taken as the fraction of "value" targets damaged. Value targets are defined as those targets contributing to overall force projection and would include non-strategic military bases, facilities for defense production, and military leadership. The numbers of these targets were assumed to be 2500 for Russia, and 1600 for the U.S. The value of all targets was assumed to follow a Pareto distribution, namely the value damaged was distributed as a function of the square root of the number of attacking warheads divided by the total number of targets. Under these assumptions, the Russian retaliation was degraded severely no matter which Russian force posture was assumed as a function of an increased U.S. defense potential against re-entry vehicles. Even with heroic efforts by the Russians to put more of each element of their strategic forces on alert (up to the entire inventory), the damage to U.S. value targets decreased with increasing levels of U.S. defenses. The most promising option for Russia was to deploy more ballistic missile submarines to offset the effectiveness of a U.S. ballistic missile defense. For this reason, it is clear that some other method of countering U.S. defense capabilities will be needed.

Russian retaliation could be improved if perfect decoys were sent to accompany all of their re-entry vehicles (RVs). The major assumption in this part of the analysis was that the ratio of decoys to RVs would be set to two. Each part of the Russian strategic force on alert or on line rate was examined. Under these conditions, the Russian SLBM force could offset the most

extreme U.S. defenses by doubling their at-sea rate. While a single strategy of doubling the at-sea rate of SLBM warheads would suffice, another posture of greater alert across the strategic retaliatory forces was also examined. Some combination of increased alert rates for the bombers, away from garrison rates for mobile ICBMs, and increased at-sea rates (more than 30%) for SLBMs would also improve Russian damage to U.S. value targets if the ratio of perfect decoys to RVs was set at two. The value of this ratio does not indicate that each RV would be accompanied by two decoys, but rather the decoys would be allocated so that no matter where the defense tries to aim his interceptors, an equal value of targets would be saved.

One critical issue is that of the credibility of decoys accompaning the re-entry vehicles. One of the models of balllistic missile defense used in this analysis permitted examination of this issue. The results indicate that as decoys become less credible, more will need to be sent to preserve the potential degradation of ballistic missile defenses. The measure used in this analysis was the confusion factor. When there is confusion on the part of the defender, he must deal with two probabilities: the probability that an RV is perceived as a decoy, and the probability that a decoy is perceived as an RV. When these two probabilities are set equal, then their numerical value is the confusion factor. For example, when the confusion factor is 0.5 or more, then the decoys are perfect. When the confusion factor is 0.0, then the decoys are not credible. It was found that if the confusion factor was lowered from 0.5 to 0.4, then the defense effectiveness was also lowered, but very slightly. If the confusion factor was lowered even more, then defense effectiveness was degraded noticably. Under these degradations, the attacker has the option of sending more decoys, if he can assess the confusion factor of the defending system. The following table indicates the number of imperfect decoys that the attacker must send to preserve the same effectiveness provided by a ratio of perfect decoys to RVs of two. The number of decoys increases rapidly as the confusion factor is decreased and may raise questions concerning payload limitations of various Russian ballistic missiles.

Table 3 - Effect of Confusion to an Attacker

Confusion Factor	Ratio of Decoys to RVs Needed to Offset Defense
0.5 (Perfect decoys)	2 (Base case)
0.3	4
0.2	8
0.1	18

The entries in this table are relative to that of perfect decoys. For example, if the confusion factor falls to 0.1 (fairly good discrimination between decoys and RVs), then the attacker must achieve a ratio of partially credible decoys to RVs of eighteen to achieve the same damage level as would be achieved with a ratio of perfect decoys to RVs of two.

First strike stability is a measure of one facet of crisis stability. First strike stability is a two-sided measure involving the force structures, force postures, and defensive capabilities of both sides. Postures that include higher alert rates tend to increase first strike stability. As in previous analyses [1], the deployment of ballistic missile defenses on both sides degrades first strike stability. If both sides employ decoys to lessen the effectiveness of their opponent's ballistic missile defenses, then first strike stability degradation is lessened. If Russia were to deploy ballistic missile defenses, it is not at all clear that the U.S. should deploy defenses in response. In this situation, first strike stability would not degrade so rapidly with the deployment of more Russian ballistic missile defenses, if the U.S. were to refrain from a similar deployment. It appears, as a result of this analysis, that another option for the U.S. would be to ride out an attack and equip their ballistic missiles with decoys to offset the effect of Russian ballistic missile defenses. Under this option for the U.S., first strike stability would remain almost constant for deployments of Russian defense potential (up to about 1000 units). An investment in decoys is likely to be much less than an investment in ballistic missile defense for the U.S.

From the viewpoint of this author, the foregoing analyses seem to indicate that both sides would be better off not to deploy extensive ballistic missile defenses in their homelands. In the future, countering ballistic missile threats from third world nations may be of greater concern. In future agreements between Russia and the U.S., maintenance of force postures that deter attacks by either side should be the main concern of defense analysts and arms control negotiators. Theater missile defenses should be deployed to protect each nation's interests ouside of their homelands. Theater missile defenses should be limited only by geographical bounds so that the strategic forces of either the U.S. or Russia will not be threatened by tactical anti-ballistic missile systems. If strategic forces of the U.S. and Russia are further reduced as a result of new negotiations, the lower limits on force reductions may well be determined by the nuclear inventories of other nations as well as Russian and U.S. capabilities to counter threats outside of their homelands.

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